INST. ENT. LIBRARY
E&A
1931

CIRCULAR No. 176 AUGUST, 1931
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

OBSERVATIONS ON THE SATIN MOTH AND ITS NATURAL ENEMIES IN CENTRAL EUROPE

By R. C. Brown, *Assistant Entomologist, Division of Forest Insects, Bureau of Entomology*[1]

CONTENTS

	Page		Page
Introduction	1	Natural enemies of the satin moth in Europe	6
Economic importance:		Hymenopterous parasites	8
In Europe	2	Tachinid parasites	13
In North America	2	Other natural enemies	15
Scope of investigations in Europe	3	Discussion of the factors which brought about control of the satin moth at the different observation points near Budapest	16
Habits and life history in central Europe	4	Summary	17
Nature of poplar and willow stands in central Europe	5	Literature cited	18
Food preferences shown by satin moth larvae in Europe	5		
Discussion of points where observations were made	6		

INTRODUCTION

The satin moth (*Stilpnotia salicis* L.) was first brought to the attention of the Bureau of Entomology, United States Department of Agriculture, on June 22, 1920. Investigations made at that time showed that the insect had probably been present in the New England States for a number of years. In July of the same year the species was found in British Columbia, Canada, and in 1922 it was discovered in the State of Washington. The discovery of the satin moth in the United States and early investigations have been discussed in detail by Burgess and Crossman (*2*, *3*).[2]

The satin moth was probably introduced into North America from Europe, where it is widely distributed, having been reported from nearly all countries on the Continent and also from the British Isles. It is apparently distributed over the greater part of Asia as well. Man has undoubtedly played an important part in the distribution of the insect by transporting forest and nursery products from one country to another. Because of the protective resemblance of the hibernation webs to the bark, the small larvae which hibernate under bark and in crevices on the bark are likely to pass unnoticed. *Stilpnotia salicis* apparently feeds exclusively upon poplar and willow, which are planted mainly for ornament and shade. Throughout central Europe the roads are often lined with poplars, and long rows may be frequently seen on estates and in parks and cemeteries.

[1] The writer wishes to thank C. W. Collins, in charge of the laboratory, C. F. W. Muesebeck, P. B. Dowden, T. H. Jones, and other members of the staff of the gipsy moth laboratory for helpful suggestions made in connection with the preparation of this circular.

[2] Italic numbers in parentheses refer to Literature Cited, p. 18.

ECONOMIC IMPORTANCE

IN EUROPE

From an economic standpoint the satin moth does not occupy a place of primary importance at the present time. One could hardly place it in the same class with such insects as *Lymantria monacha* L., *Dendrolimus pini* L., *Bupalus piniarius* L., and *Porthetria dispar* L., the reason, of course, being that poplar and willow are not of the same economic importance as conifers and oaks. The economic value of poplar and willow is, however, not insignificant, for these species, especially poplar, rank among the most important shade and ornamental trees. Complete defoliation by an insect weakens the tree and consequently retards growth. When the trees in a row do not develop uniformly the beauty of the planting is necessarily impaired. At the time of feeding the annoyance caused by enormous numbers of caterpillars crawling over everything near the infestation is considerable.

A heavy infestation of the satin moth occurred at a bathing resort in Vienna, Austria, in the summer of 1929. Caterpillars were present in such abundance that this resort suffered a great financial loss. Guests complained of the caterpillars. Considerable annoyance was caused by a rain of excrement resulting from feeding of the larvae, and many guests suffered from irritation caused by the poisonous hairs of the caterpillars. The situation became so serious during the latter part of June and early July, when the satin moth larvae were full grown, that the bathing resort was nearly deserted. Fortunately in Europe the satin moth seldom occurs in abundance over a long period of years at the same point, for a large number of natural enemies keep the insect fairly well in check. These natural enemies will be discussed in detail later.

IN NORTH AMERICA

In North America the status of the insect is quite different from its status in Europe. Here it belongs to that group of insects which have recently been introduced from another continent and which find conditions in the new environment especially favorable when a suitable food plant is present, since most of their natural enemies are absent. *Stilpnotia salicis* has found in North America very favorable food plants among our species of poplars and willows. These species are planted in North America, as in Europe, principally for ornamental and shade purposes; there are, however, certain areas where the poplar is used for wood pulp. In southwestern Canada the black cottonwood, *Populus trichocarpa* Hooker, is a species of considerable economic value, being used largely for staves of sugar barrels and in the manufacture of woodenware (*7*). The recent discovery of the satin moth in woodland areas on poplar, *Populus grandidentata* Michx., near Kingston, N. H., is causing some alarm at the present time.[3]

It has been suggested that with the passage of time in the new environment *S. salicis* might, through adaptation or necessity, change its food plant. A European report, referred to by Burgess (*2*),

[3] Unpublished gipsy moth laboratory notes.

lists oak as one of the food plants of this species. Feeding experiments conducted at the gipsy moth laboratory have shown that larvae may develop when oak foliage constitutes a part of their food. It seems to the writer, however, that this possibility need cause no great alarm, for all observations made to the present time show that this insect restricts itself in the field exclusively to poplar and willow foliage.

SCOPE OF INVESTIGATIONS IN EUROPE

In the spring of 1926 a laboratory was established at Budapest, Hungary, by the United States Bureau of Entomology, as a substation of the gipsy moth laboratory. The principal work of this laboratory has been to study the biology of the parasites of the gipsy moth (*Porthetria dispar* L.) and the brown-tail moth (*Nygmia phaeorrhoea* Don.) and to transport certain of these parasites to the United States for the purpose of establishing them there and ultimately creating a balance of controlling factors similar to that which exists in Europe. While the major project has consisted in the study of *P. dispar* and its parasites a certain amount of time has been given to *Stilpnotia salicis* and its natural enemies.

During the spring of 1926 satin moth larvae were found in enormous numbers defoliating *Populus nigra* L. var. *italica* DuRoi in a cemetery in Budapest. In the summer and autumn of the same year Budapest and its environs were systematically scouted, the territory thus covered extending nearly 30 kilometers [4] in all directions with the city as a center. Collections of large larvae made during the summer were held for the issuance of parasites, and hibernating larvae taken in the fall and early winter were dissected. At 14 points in this area the satin moth was found to be present in varying degrees of abundance. These points were kept under observation during 1927, 1928, and 1929. Scouting in the autumn of 1928 showed that the species was present in very small numbers at only a few of the points, and in 1929 it had virtually disappeared over the whole area. This is especially remarkable because during 1926 and 1927 heavy infestations occurred at many of the points. The factors which brought about the natural control of the insect at the different points were varied. Whether or not there was some underlying cause, either biologic or climatic, which had exerted its influence over the whole area, or whether it was a mere coincidence that the species had disappeared at all points simultaneously, can be, with our present knowledge of this complicated situation, only a matter for speculation. This is, however, not the first instance where an insect has been observed to disappear suddenly and more or less completely over a fairly large area. The history of insect invasions shows instance after instance where this has been the case.

A heavy infestation of *S. salicis* was found at Vienna, Austria, on November 14, 1927, and in June and July of the following year approximately 50,000 large caterpillars were collected and held at a temporary laboratory, located near the infestation, for the issuance of parasites. Work in rearing larvae was again conducted at this point in the summer of 1929, and this work, conducted on a large

[4] One kilometer equals 0.62 mile.

scale, furnished material for shipment to the United States. Parasites thus obtained consisted largely of several species of Tachinidae and a species of Meteorus. This point has been kept under observation since the discovery of the infestation and it has been found that the situation here was quite different from that in the environs of Budapest. Although a marked decrease occurred in the infestation on those trees where the insect was abundant in 1927 and 1928, the poplars immediately adjoining, as well as other poplars in the area within a radius of approximately 2 kilometers, were heavily infested in 1929.

Another heavy infestation of the satin moth was located at Osielsko, a suburb of Bydgoszcz, Poland, on November 28, 1927. Here a small isolated group of young willows, *Salix viminalis* L., was completely defoliated in 1927 and 1928. Little information regarding natural control agencies was obtained here. The infestation apparently disappeared completely during 1928, for not a single living satin moth larva could be found when the point was visited on April 18, 1929.

HABITS AND LIFE HISTORY IN CENTRAL EUROPE[5]

The adults of both sexes are strong fliers and are very conspicuous when at rest and when in flight. In the vicinity of Budapest, emergence of moths occurs during the latter half of June. Mating takes place shortly after emergence, and eggs are deposited in patches which are roughly oval in shape and are very conspicuous, being covered by a white secretion, which, upon hardening, presents a glistening appearance. The eggs are usually deposited on the trunks or on the under side of branches of the tree, but they have also been observed on objects near by and, in heavy infestations, even on grass. Egg deposition takes place from about the first to the middle of July. Hatching begins during the first week in July and reaches a maximum about July 15.

The larvae pass through two stages and spin tough, compact hibernation webs. These webs are formed under loose pieces of bark as well as in crevices and abrasions on the bark. Exposed hibernation webs are very inconspicuous because of their striking resemblance to the bark. Certain European writers (*1*, *6*, *9*) state that the satin moth passes the winter in the egg stage. Observations made both in Europe and North America show that this is certainly not the case. Larvae molt soon after forming the hibernation webs and pass the winter normally in the third stage. Sometimes warm, sunny weather in the fall will cause a number of larvae to leave their hibernation quarters. This was especially noticeable at Rómaifürdö (about 7 kilometers north of Budapest), where on November 16, 1928, a considerable number of satin moth larvae were seen crawling on the bark. These larvae did not spin new webs and therefore probably perished. In the vicinity of Budapest normal emergence of larvae from the hibernation webs begins about April 15 and continues until the first part of May. The satin moth passes through four larval stages after leaving the hibernation web and reaches the last stage normally about June 10, at which time the larvae spin loose cocoons,

[5] Descriptions of larva, pupa, and adult were published in 1927 (*3*).

in which pupation takes place. The cocoons are often formed by spinning leaves together, but they may also be found in crevices on the bark. Pupation takes place usually from June 15 to 20.

The rapidity of development of this species depends very largely upon local conditions and sometimes varies considerably at points which are comparatively near. The rapidity with which the larvae develop depends greatly upon the species of trees on which they occur, as shown by observations made in Kerepesi Cemetery, in Budapest, and at Kispest, a suburb of that city. Poplars at these two points, which are separated by a distance of about 3 kilometers, were found to be infested by the satin moth in the summer of 1927. Observations made on July 27, 1927, showed that at the former point, where the infestation was on *Populus nigra* var. *italica*, many moths were present and eggs had already been deposited, while at the latter point, where the infestation was on *P. alba* L., no moths were seen but the species was still in the larval stages. Development at the latter point was retarded by at least 10 days. In the same forest at Kispest, separated by about 500 meters from the infestation on *P. alba*, an infestation on *P. nigra* L. occurred, where development of the insect was distinctly more rapid than on *P. alba*.

At times a partial second generation of the satin moth occurs in the vicinity of Budapest. This was especially noticeable at Kerepesi Cemetery in 1926, when it was observed at the time of hibernation of the young larvae that a considerable number had developed beyond the third stage. On July 20, 1926, many larvae were about one-third grown, and subsequent observations showed that a considerable number became half grown. On August 24 a pupa of the second generation was found, and from this a male moth issued on August 26.

NATURE OF POPLAR AND WILLOW STANDS IN CENTRAL EUROPE

As has already been stated, poplars and willows are planted principally along roads, streets, and walks, in parks and cemeteries, and on estates. *Populus nigra* var. *italica* is by far the most common, but there are also large numbers of *P. nigra*. In a few instances these two have been noted in mixed stands of natural growth. *P. alba* is of least importance among the species of poplar and when present occurs usually as a low bushy growth. Willow is much less commonly planted than poplar, although many species are used as ornamental trees and a considerable amount of wild growth occurs in meadows. Of the many species of willow, *Salix viminalis* L. is the most common.

FOOD PREFERENCE SHOWN BY SATIN MOTH LARVAE IN EUROPE

Food preference, based on rapidity of development of larvae, has been mentioned under Habits and Life History in Central Europe. *Populus nigra* var. *italica* is by far the most favored species, but *P. nigra* may also be considered a preferred food plant. Of the poplars, *P. alba* is the least favored, for when the foliage of this species constitutes the food of the larvae their development is distinctly retarded. In Europe infestations have been found to be more common on poplar than on willow, and it seems safe to say that

species of poplar are, in general, distinctly preferred as food plants. A small group of willows at Osielsko, in the outskirts of Bydgoszcz, Poland, was, however, completely defoliated by the satin moth in the summers of 1927 and 1928.

DISCUSSION OF POINTS WHERE OBSERVATIONS WERE MADE

The satin moth situation at 17 points in and near the city of Budapest has been studied during the period 1926 to 1929, inclusive. The accompanying map (fig. 1) shows the relative location of these observation points. With the following exceptions, all infestations occurred on short isolated rows of poplars which lined streets, roads, or railroads. At Aquincum and Rómaifürdö there are a number of long rows of poplars, and these two points might be considered as belonging to the same poplar complex. The infestations have been confined, however, to short sections of these poplar rows. Near Rákospalota the whole countryside was crisscrossed with long rows of poplars. On one of these rows a section about 100 meters long was infested by the satin moth. At Kispest the infested poplars were in a mixed stand of *Acer* spp., *Quercus* spp., and *Acacia* spp. As is shown by the map, these points are located on both sides of the Danube, except one which is on an island in the river. The topography of the whole area is uniform; therefore the climatic conditions are probably much alike at all points. Considerable willow, representing several species, occurs near many of the points as a low bushy growth.

At Vienna, Austria, the infestation was on a long row of poplars parallel to and about 100 meters from the Danube River. The nearby meadows are interspersed with many rows and groups of poplars and considerable willow growth.

At Osielsko, Poland, the satin moth infestation occurred in an isolated 1-acre stand of young willows, *Salix viminalis.*

NATURAL ENEMIES OF THE SATIN MOTH IN EUROPE

A study of the natural enemies of the satin moth in the environs of Budapest and in Vienna has been conducted during the period 1926 to 1929, inclusive. This work has, of necessity, been incomplete, for it has been impossible to give undivided attention to this insect and its natural enemies and, consequently, the investigations have been far from exhaustive. It is hoped, however, that some facts have been learned which will give a better understanding of the insect and the factors which help in bringing about its natural control in Europe.

In regard to these control factors it should be stated that some of the natural enemies of the satin moth have been established in New England in connection with the importation of the parasites of the gipsy moth (*Porthetria dispar*) and the brown-tail moth (*Nygmia phaeorrhoea*) and that they have been found to attack the satin moth in its new home. One of these parasites, a chalcidoid, *Eupteromalus nidulans* (Thomson), which is a very important controlling factor in Europe, is also of considerable importance in the New England States. *Compsilura concinnata* Meig., a tachinid, is at times a very

important enemy of the satin moth in New England. *Sturmia scutellata* R. D., also a tachinid, and *Calosoma sycophanta* L., a predacious beetle, which are among the most important of the established enemies of the gipsy moth, at times attack the satin moth. A few instances of parasitism by native species of Tachinidae and

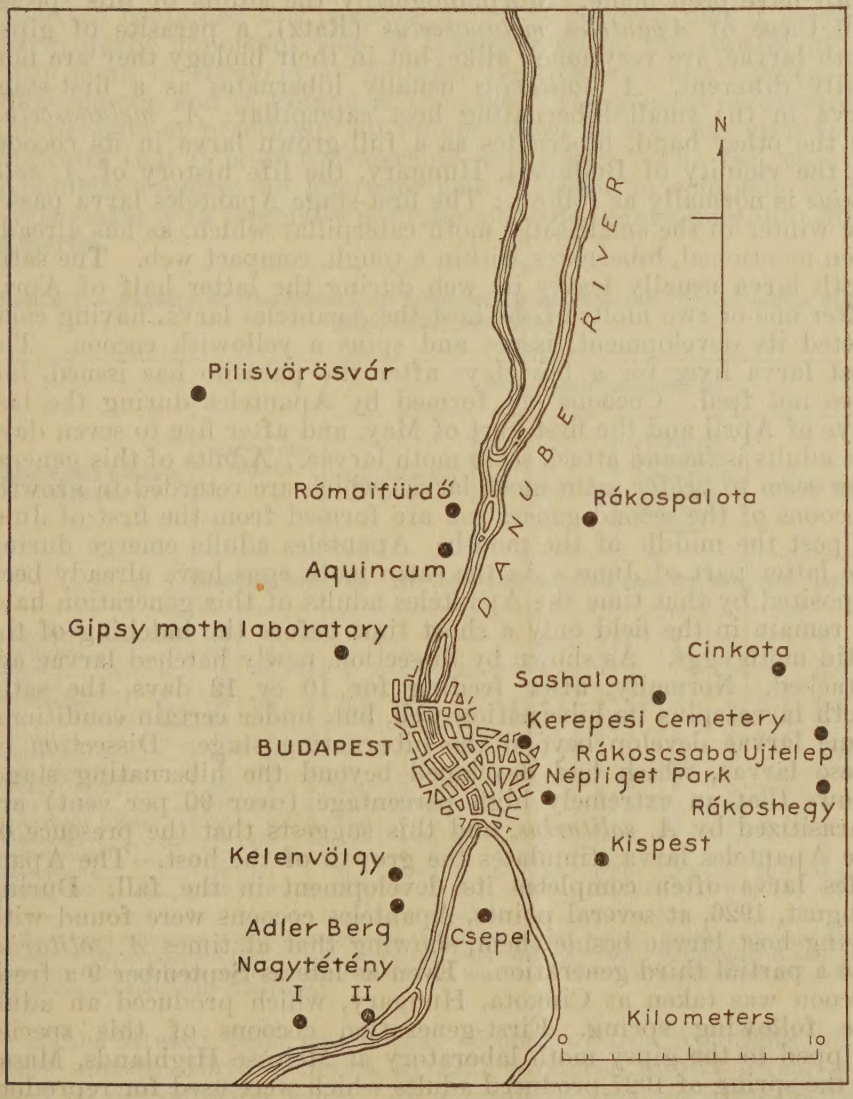

FIGURE 1.—Location of observation points in the environs of Budapest, Hungary

Hymenoptera have been recorded, but as controlling factors these native parasites are apparently of negligible importance. The combined influence of the introduced and native species, together with other controlling factors, does not keep the satin moth in check in New England.

HYMENOPTEROUS PARASITES

APANTELES SOLITARIUS RATZEBURG

This solitary species of Apanteles has been found generally distributed throughout central Europe where observations on the satin moth have been made. Morphologically the adults of this species and those of *Apanteles melanoscelus* (Ratz), a parasite of gipsy moth larvae, are very much alike, but in their biology they are normally different. *A. solitarius* usually hibernates as a first-stage larva in the small hibernating host caterpillar; *A. melanoscelus*, on the other hand, hibernates as a full-grown larva in its cocoon. In the vicinity of Budapest, Hungary, the life history of *A. solitarius* is normally as follows: The first-stage Apanteles larva passes the winter in the small satin moth caterpillar which, as has already been mentioned, hibernates within a tough, compact web. The satin moth larva usually leaves its web during the latter half of April. After one or two molts of the host the Apanteles larva, having completed its development, issues and spins a yellowish cocoon. The host larva lives for a few days after the parasite has issued, but does not feed. Cocoons are formed by Apanteles during the last days of April and the first part of May, and after five to seven days the adults issue and attack satin moth larvae. Adults of this generation seem to prefer satin moth larvae which are retarded in growth. Cocoons of the second generation are formed from the first of June to past the middle of the month. Apanteles adults emerge during the latter part of June. As the satin moth eggs have already been deposited by that time the Apanteles adults of this generation have to remain in the field only a short time before the hatching of the satin moth eggs. As shown by dissection, newly hatched larvae are attacked. Normally, after feeding for 10 or 12 days, the satin moth larva spins its hibernation web, but, under certain conditions, some larvae develop beyond the hibernating stage. Dissection of these larvae, which had developed beyond the hibernating stage, shows that an extremely high percentage (over 90 per cent) are parasitized by *A. solitarius*, and this suggests that the presence of the Apanteles larva stimulates the growth of the host. The Apanteles larva often completes its development in the fall. During August, 1926, at several points, Apanteles cocoons were found with living host larvae beside them, showing that at times *A. solitarius* has a partial third generation. Even as late as September 9 a fresh cocoon was taken at Cinkota, Hungary, which produced an adult the following spring. First-generation cocoons of this species shipped to the gipsy moth laboratory at Melrose Highlands, Mass., in the spring of 1927 produced adults which were used for reproduction work. Considerable reproduction was obtained on *Stilpnotia salicis*, *Porthetria dispar*, *Hemerocampa leucostigma* S. and A., and *Notolophus antiqua* L. through two generations. Some material of this species obtained by reproduction work passed the winter as cocoons and produced adults in the spring of 1928. Thus it is seen that the species can hibernate in two distinct ways: (1) As a first-stage larva in its host; and (2) as a full-grown larva in its cocoon. This second manner of hiberation further suggests the close relation-

ship between this species of Apanteles and *Apanteles melanoscelus* Ratz.

Judging from dissections which have been made from collections of hibernating satin moth larvae, *A. solitarius* may, at times, be an important controlling factor. (Table 1.) Parasitism has in no case been high, but in several instances more than 10 per cent of the larvae dissected contained this parasite, and it is believed that it played a particularly important rôle in bringing about the control of the satin moth in Hungary at Népliget Park, Rákoscsaba Ujtelep, and Rákospalota, and in Poland at Osielsko. The general occurrence of the parasite at practically all points where its host has been found indicates that it is of considerable importance. The fact that the Apanteles requires no alternate host in order to complete its life cycle makes it an especially desirable parasite to introduce into North America.

TABLE 1.—*Results of dissections of hibernating satin moth larvae made during 1926, 1927, and 1928*

Observation points in Hungary	Larvae dissected [1]			Percentage of parasitism by—											
				Apanteles solitarius			Meteorus sp.			Undetermined hymenopteron (possibly Rogas unicolor)			All species		
	1926	1927	1928	1926	1927	1928	1926	1927	1928	1926	1927	1928	1926	1927	1928
Adler Berg	53	0	0	11.3	0	0	1.9	0	0	0	0	0	13.2	0	0
Aquincum	26	23	0	3.8	0	0	0	8.7	0	0	0	0	3.8	8.7	0
Csepel	0	200	25	0	9.5	0	0	3.0	0	0	.5	0	0	13.0	0
Cinkota	89	0	0	7.8	0	0	0	0	0	0	0	0	7.8	0	0
Kelenvölgy	190	108	0	11.0	20.3	0	5.8	6.4	0	0.5	5.5	0	17.3	32.2	0
Kerepesi Cemetery	206	0	0	7.3	0	0	.5	0	0	0	0	0	7.8	0	0
Kispest	12	0	0	0	0	0	91.6	0	0	0	0	0	91.6	0	0
Nagytétény I	14	30	0	0	6.6	0	0	0	0	0	0	0	0	6.6	0
Nagytétény II	0	137	0	0	3.6	0	0	2.1	0	0	13.8	0	0	19.5	0
Népliget Park	81	4	0	28.3	0	0	33.3	0	0	0	0	0	61.6	0	0
Pilisvörösvár	308	101	2	6.1	9.9	0	.3	0	0	0	0	0	6.4	9.9	0
Rákoscsaba Ujtelep	10	0	0	30.0	0	0	0	0	0	0	0	0	30.0	0	0
Rákoshegy	79	162	3	1.2	4.9	0	6.3	1.2	0	0	.6	0	7.5	6.7	0
Rákoskerestur	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rákospalota	78	141	0	21.8	9.9	0	0	2.8	0	0	2.1	0	21.8	14.8	0
Rómaifürdö	465	0	0	6.9	0	0	.4	0	0	.2	0	0	7.5	0	0

[1] In all cases collections of larvae were made in the late fall or early winter. It will be observed that the number of larvae dissected from certain observation points was very small. Infestations at such points were very light and larger collections of larvae were not possible. At points where no larvae were dissected the species had apparently disappeared.

It has already been stated that cocoons of this Apanteles which were sent to North America in 1927 produced adults which were used in reproduction work. As a result of this work the parasite was colonized at certain points in the United States where the satin moth occurred, and subsequent recoveries at these points indicate that the species has perhaps gained a foothold here. It is not possible, as yet, to state that the parasite is positively established, but the outlook is certainly optimistic.

METEORUS SP.

Another braconid parasite which has been found at several points near Budapest, Hungary, and at Vienna, Austria, is a species of Meteorus. This parasite was not found as generally as *Apanteles solitarius*, but observations show that at certain points it was of primary importance. As far as is known this species of Meteorus is morphologically and biologically identical with *Meteorus versicolor* Wesm., a larval parasite of the brown-tail moth, differing only in host selection. This parasite of the brown-tail moth has been present in North America for many years but has not been reared from the satin moth here. At the present time considerable experimental work is being done in an attempt to solve this Meteorus problem.

In the vicinity of Budapest the life-history of *Meteorus* sp. from *Stilpnotia salicis* is as follows: The first-stage Meteorus larva passes the winter in the hibernating larva of its host. The host caterpillars begin to leave their webs about April 15, and the Meteorus larvae resume development and become full grown during the first part of May. The larva issues from its host and spins a cocoon which is suspended by a characteristic, strong, silken thread. In seven or eight days the adults emerge and attack the satin moth larvae for a second generation, cocoons being formed during the latter part of June and adults issuing early in July. The second-generation Meteorus attacks larvae that are more than half grown and issues usually from the last larval stage of its host. Most caterpillars in the larger stages from which parasite larvae have issued do not die immediately but often live for several days, during which time they writhe considerably but have not been seen to feed. The period when adults of this parisite issue coincides with the period when satin moth eggs hatch. Very small satin moth larvae are attacked, as shown by dissection. The second-stage host larva spins its hibernation web, then molts, and normally remains there until the following spring, but under some conditions, as has already been stated in the discussion of *Apanteles solitarius*, some satin moth larvae develop beyond the hibernating stage, and, as in the case of the Apanteles larva, the Meteorus larva continues to develop. On July 30, 1926, a collection of satin moth larvae which had developed beyond the hibernating stage was made at Kerepesi Cemetery, Budapest. Four Meteorus larvae issued from these caterpillars and formed cocoons August 4 to 7, from which adults issued about August 15.

The most striking instances when this parasite was observed to be important were in 1926 at Népliget Park and Kispest, both points being on the eastern outskirts of the city of Budapest. Dissection of 81 satin moth caterpillars from the former point showed that 27 contained first-stage Meteorus larvae, and at the latter point, where only 12 caterpillars could be found, 11 were found to be parasitized by this Meteorus. The infestations at both points were very light and were undoubtedly on the decline, and it would seem that this species was a very important parasite at each point. Table 1 shows that the parasite was present at several points in Hungary, but was not outstanding except at the places mentioned above. At Vienna, Austria,

in the summer of 1929, this parasite was reared in considerable numbers from large larvae of the satin moth, and about 4,000 cocoons were shipped to the United States.

ROGAS UNICOLOR WESMAEL

Two adults of this species were reared from the satin moth, material being obtained from Rómaifürdö, Hungary. The adults issued from their cocoons, which were formed within the larval skin of the host, on July 3 and 5, 1927, respectively. The life history and habits of this species are not, as yet, known. Dissections of hibernating satin moth caterpillars have shown the presence, at a number of points, of an "undetermined hymenopteron." It seems possible that the so-called undetermined hymenopteron may be an immature stage of *Rogas unicolor*. A special effort was made in 1928, at Nagytétény II, Hungary, where this undetermined hymenopteron was found in some numbers the preceding year, to get material for further study, but not a single specimen could be obtained. The species appears to be of very little value as a parasite of *S. salicis*.

EUPTEROMALUS NIDULANS (THOMSON)

This chalcidoid parasite, which feeds externally on the small hibernating larvae of *S. salicis*, has been noted at several points near Budapest and also in the infestation at Vienna. During the fall collections of *salicis* larvae in 1926 the parasite was discovered at Aquincum, a suburb of Budapest, located about 6 kilometers north of the city. Here a heavy infestation of the satin moth was present during the summer, and enormous numbers of larvae spun hibernation webs. The first observations were made at this point on November 4; at that time it was estimated that 90 per cent of the larvae were dead and that the principal cause was the parasite *Eupteromalus nidulans*. Large numbers of full-grown larvae of this chalcidoid were found in the webs, and two weeks later not a single living hibernating caterpillar could be found after a careful search. The following spring many parasite larvae were found in the webs. Some contained two parasite larvae, and in one instance three, and it was noted that when this occurred the larvae were much smaller than usual, although undoubtedly full grown. At Rákoscsaba Ujtelep, about 6 kilometers northeast of Budapest, a fairly heavy infestation of the satin moth was greatly reduced by this parasite. At this point it was estimated that over 50 per cent parasitism of the hibernating larvae by this species had occurred. The species was also found in considerable numbers in hibernation webs at Rómaifürdö, Hungary. Small numbers have been noted at Cinkota, Kelenvölgy, Rákoshegy, and Adler Berg, all points within a few kilometers of Budapest. In the autumn of 1928 the species was again encountered in a heavy satin moth infestation at Vienna, Austria. Here, on September 20, *Eupteromalus nidulans* was found to be present in enormous numbers, and it was estimated that about 75 per cent of the hibernating satin moth larvae had been killed by this species. Many pupae were noted at that time, indicating that another partial generation of the parasite would occur before winter. In several instances two and, in one case, three larvae of *E. nidulans* were

found in a hibernation web of its host. This heavy parasitism resulted in a marked reduction in the infestation.

Eupteromalus nidulans has already been established in the United States in connection with the importation of parasites of the brown-tail moth (*Nygmia phaeorrhoea*). Observations made in New England in heavy infestations of the brown-tail moth show that it is present at times in fairly large numbers, being parasitic on the small hibernating larvae as in the case of the satin moth. This chalcidoid is a satin moth parasite of considerable importance in New England, one instance of as high as 58 per cent parasitism having been reported.[6] The species belongs to a group, the Pteromalidae, many of the members of which are secondary parasites. *E. nidulans* is indeed no exception, for it often appears in the rôle of a secondary parasite. It has been reared in New England from *Apanteles melanoscelus* (Ratz.), *A. lacteicolor* Vier., *A. glomeratus* L., *A. hyphantriae* Riley, and *A. euchaetis* Ashm. (*5*). As a secondary parasite of these species it is ectoparasitic within the host cocoon. The conditions under which it acts as a primary parasite are essentially the same as when it plays a secondary rôle, for the larval web in which feeding takes place is analogous to the host cocoon of the primary parasite.

TELENOMUS MAYRI KIEFFER [7]

At three points in Hungary, and at Vienna, Austria, these minute parasites were obtained from collections of satin moth eggs. The highest degree of parasitism observed occurred at Galgamacsa, Hungary, in 1926. A light infestation of *Stilpnotia salicis* was present at that point during the summer, and the egg deposition was small, but the percentage of eggs which were parasitized was fairly high. Eggs were deposited from July 5 to 10, and adults of *T. mayri* issued from July 24 to August 5. In the summer of 1927 egg collections from Rákospalota and Kelenvölgy, Hungary, produced these parasites in some numbers. Satin moth infestations at both points were light, and only a small number of eggs could be obtained. Two hundred and fifty adults of *T. mayri* obtained from eggs collected there were sent to the United States. An attempt was made to reproduce the species in the laboratory at Melrose Highlands, Mass., on eggs of various Lepidoptera. Eggs from about 25 different species of Lepidoptera were tried, but only slight and not at all natural oviposition was secured on eggs of two species, namely *P. dispar and Olene* sp. It is evident that this species attacks the eggs of other Lepidoptera, for it is multiple-brooded and can not hibernate in satin moth eggs. It may, however, hibernate as an adult, but this has not, as yet, been determined. Adults of this serphoid egg parasite can be held for a long time in the laboratory. Of 48 adults which issued August 2 to 5, 35 were living on September 4, and 20 were still alive on October 5. In 1928 about 100 adults of this species were obtained from 450 egg masses taken at Vienna, Austria. That the species is of prime importance as a parasite of *salicis* is rather doubtful. It does, however, play a certain part, if only a small one, as an enemy of its injurious host.

---

[6] Unpublished gipsy moth laboratory notes.

[7] Determined by A. B. Gahan, division of taxonomy and interrelations of insects, Bureau of Entomology, U. S. Department of Agriculture.

TACHINID PARASITES

CARCELIA GNAVA MEIGEN

This tachinid parasite has for some years been misidentified. *Carcelia* spp., reared from *S. salicis* and also from *P. dispar*, were sent from the Budapest laboratory to Joseph Villeneuve of Rambouillet, France, for identification. The Carcelia species reared from *P. dispar* was identified by him as *C. separata* Rond. and that reared from *S. salicis* as *C. gnava*. The two species, while very much alike, may readily be separated by morphological differences pointed out by Doctor Villeneuve in correspondence with workers at the Budapest laboratory.

In the summer of 1927 the true *Carcelia gnava* was reared in large numbers from satin moth larvae and pupae taken at Kelenvölgy, Hungary. On the same poplar trees 93 larvae of *P. dispar* were found, from which 4 Carcelia pupae were obtained. All of the pupae reared from *P. dispar* produced adults of *Carcelia separata*. These two species of Carcelia show practically absolute preference for the satin moth and gipsy moth, respectively, when the two hosts occur together. In this connection it might be mentioned that at points where large-scale rearing work has been conducted no instance has occurred where *C. separata* has been reared from *S. salicis* and only one instance where *C. gnava* has been reared from *P. dispar*.

As a parasite of *S. salicis*, *Carcelia gnava* ranks among the most important, and among the tachinid parasites it receives, without doubt, first place. The biology of the species has not as yet been completely worked out. Sellers [8] observed that this species mates preferably at dusk and remains in copulation about 15 minutes. Eggs are laid on the ends of the hairs, and the maggots crawl down these hairs and burrow immediately through the body wall of the host. The egg hatches instantaneously after deposition. Although a special attempt has been made to secure information regarding the hibernation of this species, the problem remains as yet unsolved. Large collections of miscellaneous lepidopterous larvae have been made at points where *Carcelia gnava* was known to have been present. Two specimens of *C. gnava* have been reared from *Malacosoma neustria* L. collected at Doboz and Simontornya, Hungary.

In the vicinity of Budapest issuance of *Carcelia gnava* maggots from *S. salicis* usually begins about June 15 and reaches a maximum about June 20. Issuance of adults occurs during the first half of July. At Kelenvölgy, Hungary, *C. gnava* was a very important parasitism of these satin moth larvae by *C. gnava* was, therefore, made June 12 to 19 produced 1,024 puparia of *C. gnava*. In many instances more than one maggot issued from a host larva, and the parasitism of these satin-moth larvae by *C. gnava* was, therefore, actually much lower than one might assume from these figures. Heavy parasitism by this species occurred at Doboz, Hungary, in 1927. As a result of the large-scale rearing of satin moth larvae which was conducted at Vienna, Austria, in the summer of 1928, it was found that approximately 30 per cent of the tachinid pupae reared were *C. gnava*. Parasitism by tachinids was low at this

[8] Unpublished observations made by W. F. Sellers at the gipsy moth laboratory, Melrose Highlands, Mass.

point, for only 10 per cent of the larvae collected produced puparia. Again in 1929 this tachinid was the most important parasite reared at Vienna, Austria. *Carcelia gnava* was reared from satin moth larvae taken at practically all points during 1927 and 1928, and this fact indicates that it may play a very important rôle as an enemy of *S. salicis* in Europe. Puparia obtained by large-scale rearing of *salicis* larvae were sent to the United States.

TACHINA LARVARUM LINNAEUS

This multiple-brooded tachinid parasite possesses a long list of hosts of various types of lepidopterous larvae in Europe and is often a very important enemy of the gipsy moth. It has not been considered in the past as an important satin moth parasite. However, in the infestation at Vienna, Austria, in 1928 it was found to be nearly equal to *Carcelia gnava* as an enemy of the satin moth. Nearly 30 per cent of the tachinid pupae reared at Vienna were *Tachina larvarum*.

Tachina larvarum deposits eggs on the larva of its host. In summer from 9 to 16 days are required for development from egg to puparium. Formation of puparia at Vienna began about June 25 and reached a maximum about July 2. Maggots of *T. larvarum* issued in large part from host pupae.

Shipments of *T. larvarum* puparia have been made for several years to the United States with the hope of establishing the species here as a parasite of the gipsy moth. Because of the fact that it has been reared from such a large number of lepidopterous larvae and pupae and because of its wide distribution, it should find a host species in America which would carry it satisfactorily over periods when the more favored hosts are absent. The fact that it is at times a parasite of importance of the satin moth as well as of the gipsy moth makes its introduction and establishment in America especially desirable.

PALES PAVIDA MEIGEN

A fairly large number of hosts have been recorded for this multiple-brooded tachinid parasite. Importation of tachinid parasites of the brown-tail moth made during the period 1906 to 1909 included small numbers of this species. It has been occasionally reared from satin moth larvae in small numbers in Europe, but it was first found to be an important parasite at Vienna in 1928, when about 20 per cent of the tachinids reared from the satin moth were of this species. It is true that the total parasitism by tachinids was low at this point, but a sufficient number of puparia of this species were obtained to indicate that under the right conditions it might be of considerable value in the biological fight against the satin moth. *Pales pavida* has been reared in Europe in considerable numbers from *Thaumetopoea processionea* L. and *Acronycta tridens* Schiff. This tachinid deposits eggs upon foliage. It is a species which has been little studied, and its seasonal history has not as yet been determined.

COMPSILURA CONCINNATA MEIGEN

This well-known tachinid, which is widely distributed in Europe and possesses a multitude of hosts, has been successfully established

in America. The host relations of *Compsilura concinnata* in North America have been discussed by Webber and Schaffner (*8*). It has often been reared from *S. salicis* but can hardly be called one of the most important parasites of that species in Europe. About 10 per cent of the puparia obtained at Vienna in 1928 were *C. concinnata.* In New England it is at times an important parasite of the satin moth.

ZENILLIA LIBATRIX PANZER

Zenillia libatrix has been observed to be of some importance as a gipsy moth parasite in Europe. It has several generations a year, depending on the length of the season, and possesses a fairly long list of hosts, comprising a number of different types of lepidopterous larvae. It has been reared in the laboratory from overwintering pupae of *Pygaera pigra* Hufn. *Z. libatrix* is widely distributed, particularly in southern Europe. Eggs of the species are deposited upon foliage and are eaten by the caterpillars with their food. In summer about 15 days are required from egg to puparium, but the time necessary for development depends greatly upon the temperature. This species has been reared from *S. salicis* on three occasions. In July, 1927, one specimen of *Z. libatrix* was reared from satin moth larvae collected at Rómaifürdö, Hungary. Nearly 10 per cent of the puparia obtained from the large-scale rearing work conducted at Vienna, Austria, in 1928 were of this species, and a considerable number were obtained at this point in 1929.

PHOROCERA AGILIS ROBINEAU-DESVOIDY

Phorocera agilis, a tachinid of great economic importance as a parasite of *Porthetria dispar* and *Lymantria monacha*, was first reared from the satin moth, as far as records show, in the summer of 1928 at Vienna, Austria, and only eight puparia were obtained. The species has one generation and passes the winter in the puparium. The puparia obtained from the satin moth were formed during the period June 30 to July 9, 1928, and adults issued May 25 to 30, 1929.

OTHER NATURAL ENEMIES

PEDICULOIDES VENTRICOSUS NEWPORT

One of the most striking instances of complete and rapid annihilation of a heavy infestation of *S. salicis* occurred in Kerepesi Cemetery, Budapest, in the autumn of 1926. At that point a very heavy infestation occurred during the summer of that year. The infestation was on a row of *Populus nigra* var. *italica* which was about 200 meters long. Adults were very abundant on June 27, and many eggs had already been deposited. Observations made in August showed that enormous numbers of small larvae were present and that many had already spun hibernation webs. The infestation had spread to another group of poplars, *P. nigra*, which was about 100 meters distant. Here hibernating larvae were also present in large numbers. The presence of the predatory mite *Pediculoides ventricosus* was first discovered on September 27, when it was noted that practically every hibernation web contained a number of mites which were attached to the already dead *salicis* larvae. In the Budapest labora-

tory it was found that mites would attack and destroy larvae both within and outside the webs. A few larvae placed in a small pill box with several mites were found after a few hours to have been attacked, and all larvae were dead within 24 hours. Each larva had several mites attached to it. The infestation at Kerepesi had been practically annihilated by the invasion of mites in a comparatively short time. A careful search in early October failed to reveal a single living satin moth larva. Again in the spring of 1927 these poplars were examined, but no living *salicis* caterpillars could be found. In spite of the fact that the heavy infestation at Kerepesi Cemetery was so completely wiped out by this predator, it is doubtful if the mite plays an important part generally as an enemy of the satin moth, for the species has never been observed in other *salicis* infestations in Europe.

This species is widely distributed in North America, where it attacks a variety of hosts and has been on a few occasions a very obnoxious insect in entomological laboratories (*4*). It was first observed to attack the satin moth in 1929. In that year it was discovered in two localities, Manchester and Kingston, in New Hampshire. At the former point a considerable infestation of this mite occurred but at the latter point it was of negligible importance.[9]

BEAUVERIA GLOBULIFERA (SPEGAZZINI) PICÁRD AND ISARIA FARINOSA (DICKSON) FRIES[10]

At several points near Budapest, Hungary, and Vienna, Austria, where observations on the satin moth were made, dead hibernating larvae were found covered with white fungus. Samples of this fungus were sent to the United States, and it was found that two species were present, namely, *Beauveria globulifera* (Spegazzini) Picárd and *Isaria farinosa* (Dickson) Fries. At three of the points in Hungary—Adler Berg, Cinkota, and Sashalom—these fungi were apparently the factors which brought about the control of the satin moth.

These fungi are also present in satin moth infestations in the United States. Their status in relation to the satin moth is now being investigated at the gipsy moth laboratory.

DISCUSSION OF THE FACTORS WHICH BROUGHT ABOUT CONTROL OF THE SATIN MOTH AT THE DIFFERENT OBSERVATION POINTS NEAR BUDAPEST

It has already been stated that because of the complexity of the problem of control and because of the incomplete data at hand a satisfactory explanation of the causes which have brought about apparently complete control of the satin moth over the entire area surrounding Budapest can not be given. However, at many points certain agencies were more or less outstanding and have played an important rôle in the suppression of this pest. At some points one may state with some degree of certainty that this parasite or that predator brought about the control of the species. At other points the causes were not so apparent, and one can at best only indicate what probably occurred. It appears, perhaps, that the abundance

[9] Unpublished gipsy moth laboratory notes.
[10] Determined by W. H. Sawyer, jr., of Bates College, Lewiston, Me.

or absence of this or that parasite or predator at a certain point is merely a matter of coincidence, but it seems to the writer that there are causes which account for this abundance or absence and which remain more or less constant. To determine what conditions are responsible for the abundance of a certain parasite or predator is a problem which is very important in insect ecology. A better understanding of these conditions would be of great help in the practical project of introducing and establishing insect enemies in another country. The number of factors which exert an influence upon parasites and predators in a given environment are many and are rather bewildering to contemplate. It is believed, however, that further study along these lines should be made, and perhaps some order may be brought out of the chaos of things.

In summing up the various factors which helped to bring about control of the satin moth at the different observation points near Budapest it may be best, perhaps, to group these points as follows:

(1) Points where one factor was especially outstanding and was apparently responsible for the control of the species—

Observation point	Factor apparently responsible for control
Adler Berg	Fungous diseases
Aquincum	*Eupteromalus nidulans*
Cinkota	Fungous diseases
Kelenvölgy	*Carcelia gnava*
Kerepesi Cemetery	*Pediculoides ventricosus*
Kispest	Meteorus
Nagytétény II	"Undetermined hymenopteron," possibly *Rogas unicolor*
Sashalom	Fungous diseases

(2) Points where a combination of two factors seemed to bring about control—

Observation point	Factors apparently responsible for control
Népliget Park	*Meteorus* sp. and *Apanteles solitarius*
Rákoscsaba Ujtelep	*Eupteromalus nidulans* and *A. solitarius*

(3) Points where the causes which resulted in the control of the satin moth were not obvious: Csepel, Nagytétény I, Pilisvörösvár, Rákoshegy, Rákoskerestur, Rákospalota, and Rómaifürdö.

SUMMARY

In 1926 a substation of the gipsy moth laboratory, Melrose Highlands, Mass., was established at Budapest, Hungary, in order to carry on investigations concerning *Porthetria dispar*, *Stilpnotia salicis*, and *Nygmia phaeorrhoea*, and the natural enemies of these species, with the object of transporting certain of these enemies to the United States for establishment there. The study of *P. dispar* and its parasites has been the main project at this laboratory, but a certain amount of time has been given to *S. salicis* and its natural enemies. Observations have shown that poplars and willows are widely distributed throughout central Europe and are planted mainly for ornament and shade. Among the species of poplar, *Populus nigra* var. *italica* and *P. nigra* are the most common, and of the willows, *Salix viminalis*. It has been found that the satin moth

feeds exclusively on poplar and willow in Europe, preferring poplar. *P. nigra* and *P. nigra* var. *italica* are by far the most favored food plants. Development of satin moth larvae is distinctly retarded when foliage of *P. alba* serves as food. In only one instance have these larvae been noted in abundance feeding on willow.

During the period 1926 to 1929, inclusive, the satin moth was located in varying degrees of abundance at 17 different points within a radius of 30 kilometers of Budapest, Hungary, and also at Vienna, Austria, and at Osielsko, a suburb of Bydgoszcz, Poland.

In the vicinity of Budapest the life cycle of the satin moth is normally about the same as in New England, but occasionally a partial second generation occurs in Hungary. At one point in the fall of 1926 a considerable number of larvae developed beyond the hibernating stage. Many became half grown, and in one instance a larva completed its development, pupated, and produced a moth on August 26.

Observations have shown that hymenopterous and tachinid parasites and certain fungous diseases constitute the principal natural enemies of this species, although a predatory mite has been found to exert a strong influence in its biological control. During the period referred to heavy infestations have occurred at some of the points near Budapest, but in the autumn of 1929 they had practically disappeared over the whole area. This sudden disappearance suggests that perhaps other factors, either biologic or climatic, the nature of which is not yet understood, may have been the underlying cause of control.

Large-scale rearing work conducted in an infestation at Vienna, Austria, in 1928 and 1929 gave considerable information, particularly regarding tachinid parasites of the satin moth, and furnished material for shipment to the United States.

LITERATURE CITED

(1) BERGE, F.
1910. SCHMETTERLINGSBUCH NACH DEM GEGENWÄRTIGEN STANDE DER LEPIDOPTEROLOGIE. Neu bearb. und hrsg. von H. Rebel, Aufl. 9. 518 p., illus. Stuttgart.

(2) BURGESS, A. F.
1921. THE SATIN MOTH: AN INTRODUCED ENEMY OF POPLARS AND WILLOWS. U. S. Dept. Agr. Cir. 167, 16 p., illus.

(3) ——— and CROSSMAN, S. S.
1927. THE SATIN MOTH, A RECENTLY INTRODUCED PEST. U. S. Dept. Agr. Bul. 1469, 23 p., illus.

(4) HOWARD, L. O., and FISKE, W. F.
1911. THE IMPORTATION INTO THE UNITED STATES OF THE PARASITES OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH. U. S. Dept. Agr., Bur. Ent. Bul. 91, 344 p., illus.

(5) MUESEBECK, C. F. W., and DOHANIAN, S. M.
1927. A STUDY IN HYPERPARASITISM, WITH PARTICULAR REFERENCE TO THE PARASITES OF APANTELES MELANOSCELUS (RATZEBURG). U. S. Dept. Agr. Bul. 1487, 36 p., illus.

(6) NÜSSLIN, O.
1927. FORSTINSEKTENKUNDE. Neubearb. und verm. aufl., hrsg. von L. Rhumbler. Aufl. 4, 625 p., illus. Berlin.

(7) SARGENT, C. S.
1905. MANUAL OF THE TREES OF NORTH AMERICA (EXCLUSIVE OF MEXICO). 826 p., illus. Boston and New York.

(8) WEBBER, R. T., and SCHAFFNER, J. V., JR.
1926. HOST RELATIONS OF COMPSILURA CONCINNATA MEIGEN, AN IMPORTANT TACHINID PARASITE OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH. U. S. Dept. Agr. Bul. 1363, 32 p.

(9) WOLFF, M., and KRAUSSE, A.
1922. DIE FORSTLICHEN LEPIDOPTEREN; SYSTEMATISCHE UND BIOLOGISCHE ÜBERSICHT SÄMTLICHER SCHÄDLICHEN UND DER HARMLOSEN ARTEN DES DEUTSCHEN SPRACHGEBIETES UNTER MITBERÜCKSICHTIGUNG WICHTIGER AUSSERDEUTSCHER PALÄARKTISCHER ARTEN; ZUM GEBRAUCH FÜR ZOOLOGEN, FORSTWIRTE UND STUDIERENDE DER FORSTWISSENSCHAFT, SOWIE FÜR FREUNDE DER ENTOMOLOGIE. 337 p. Jena.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	W. G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	E. L. MARSHALL.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration	LEE A. STRONG, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	————, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This circular is a contribution from

Bureau of Entomology	C. L. MARLATT, *Chief.*
Division of Forest Insects	F. C. CRAIGHEAD, *Principal Entomologist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 5 cents